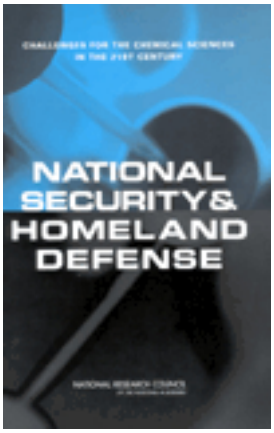
Free Executive Summary



National Security and Homeland Defense: Challenges for the Chemical Sciences in the 21st Century

Committee on Challenges for the Chemical Sciences in the 21st Century, National Research Council

ISBN: 0-309-08504-7, 122 pages, 6x9, paperback (2003)

This is the first book of seven in the Challenges for the Chemical Sciences in the 21st Century series. This book is based on discussions and presentations at a workshop, and is intended to help scientists and funding agencies set short- and long-term research agendas. It focuses on the challenges for chemists and chemical engineers with respect to threat reduction, preparation, situational awareness, and threat neutralization and remediation.

Executive Summary

The public has long recognized the potential benefits of research in chemistry and biology to the health and welfare of our society, and the relevance of that research to national security has become clearer since September 11, 2001. Chemical and biological agents can be a realistic threat to the safety of our civilian and military personnel. The nation must address these threats in the context of threat reduction, preparation, response, and neutralization and remediation. Technology alone cannot meet the goals of security and safety that our populace desires: the United States leads the world with its experts and education in the chemical sciences and these should be deployed to help us reach our security goals. We must not only incorporate current knowledge in chemistry and chemical engineering, but also engage our nation's experts in advancing the frontiers of knowledge through research to minimize the chance of a terrorist attack, minimize the extent of injury and material damage should such an attack take place, and remedy the effects of such an attack.

As a response to the events of September 11, 2001, the National Security and Homeland Defense Workshop was included as one of six workshops held as part of "Challenges for the Chemical Sciences in the 21st Century." The workshop topics reflect areas of societal need—materials and manufacturing, energy and transportation, national security and homeland defense, public health, information and communications, and environment. The charge for each workshop was to address the four themes of discovery, interfaces, challenges, and infrastructure as they relate to the workshop topic:

- Discovery—major discoveries or advances in the chemical sciences during the past several decades.

- Interfaces—interfaces that exist between chemistry/chemical engineering and such areas as biology, environmental science, materials science, medicine, and physics.
- Challenges—the grand challenges that exist in the chemical sciences today.
- Infrastructure—infrastructure that will be required to allow the potential of future advances in the chemical sciences to be realized.

The National Security and Homeland Defense workshop serves two main goals. First, it provides a mechanism to broadly engage the chemical sciences R&D community in assessing the needs and recognizing the opportunities for R&D in this important area. Second, it provides federal agencies with information that can guide and support their investment in R&D in key areas where the chemical sciences can make a unique contribution. This workshop report is complementary to *Beyond the Molecular Frontier: Challenges for Chemistry and Chemical Engineering*, the report on the future of the chemical sciences that is being produced by the Steering Committee for the "Challenges" study chaired by Ronald Breslow and Matthew V. Tirrell, and *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism*, the report produced by the National Research Council committee chaired by Lewis M. Branscomb and Richard D. Klausner that makes specific recommendations on courses of action to be taken to prepare our nation for potential terrorist attacks.

On January 14-16, 2002, the Workshop on National Security and Homeland Defense was held to identify both the challenges faced as a result of terrorist threats and the most effective means available for chemists and chemical engineers to respond to those challenges. The chemistry and chemical engineering community at large was invited to attend; those who came did so of their own volition and their interest in the subject matter and service to society. While these participants were individuals with expertise in the chemical sciences from industry, academia, and the federal government, they were not necessarily experts on national security and homeland defense issues. Furthermore, by holding an unclassified workshop, information on some existing or developing technologies could not be included in the discussions. Nevertheless, approximately 100 workshop participants were involved in stimulating presentations and discussions on the use of chemical sciences to meet the needs of national security and homeland defense. The ideas and challenges identified in these presentations, as well as the four themes listed above, were used as a starting point for breakout sessions, where the participants offered their thoughts and expanded on technical concepts and needs identified in the lectures.

Material from both the presentations and the breakout sessions was used by the committee as the basis for the findings drawn in this report. After an introductory breakout session that identified ways that the chemical sciences have contributed to national security and homeland defense throughout the past few

decades, the goal of the committee was to identify a series of grand challenges, the overarching needs and goals for effectively using the chemical sciences in the counterterrorism effort. Each of the grand challenges is composed of a series of

Some Grand Challenges for Chemistry and Chemical Engineering

- Energy independence—to reduce our reliance on foreign nations. Opportunities in the chemical sciences include the development of more efficient engines, better materials for energy storage, and alternative energy sources. More detailed information can be found in the workshop report on Energy and Transportation, part of the "Challenges" series.
- Supply chain safety—to protect the products and services on which our economy and society depend. The opportunities for chemical scientists include improved security plans at chemical production sites, automated detection systems that can sense agents inside of closed containers, and improved placarding of railroad tank cars.
- Secure chemistry—to minimize the misuse of chemicals and chemical assets as weapons of destruction. Challenges for chemical scientists include the substitution of less toxic chemicals in the manufacturing process and the minimization of the accumulation and storage of hazardous intermediates and products.
- Integrated response measures—to minimize loss of life and property. The challenges for chemical scientists include the development of detectors and information systems that can provide responses for chemical, biological, and radiological weapons to maximize the effectiveness of a diverse group of responders.
- Chemical, biological, and radiological detectors—to minimize or prevent harm. Opportunities in the chemical sciences range from the development of rugged, portable detectors for field use to better methods of sample preparation.
- Collective and personal protection systems—to avert infection or contamination. Challenges for chemical scientists include improved air filtration systems and the effect of weather patterns on agent dispersal.
- Immediate and extended medical countermeasures—to diagnose and treat infection and contamination. The opportunities for the chemical sciences include gaining a better understanding of virus replication and better computer modeling for drug design.
- Neutralization, decontamination, and disposal procedures—to safely return infrastructure and property to use. Challenges for chemical scientists range from the development of environmentally benign decontaminants to the surface science of agents and decontaminants.

more specific challenges or barriers that must be overcome to meet the goal stated in the grand challenges. Likewise, each specific challenge has related research needs, which, once met, can aid in overcoming the scientific barriers to the grand challenges.

The committee's findings to guide research on defense-related topics are listed below.

1. Extensive research opportunities exist throughout the many facets of chemistry and chemical engineering that can assist national security and homeland defense efforts.

a. Research in systems and analysis is required to apply new knowledge of basic science to developing tools and products for national security and homeland defense. Three major needs were identified at the workshop:

- **Detectors with the broadest possible range for chemical and biological agents.** New sensing and sampling technologies will yield improved threat detection and identification technologies. Specific detectors that provide speed, high sensitivity, and great reliability are essential.
- **Miniaturization of detection and identification equipment for use in the field.** This is needed by soldiers, first responders, and other emergency and military personnel. This research will also allow the development of detection systems on a chip. Understanding materials and transport phenomena at the micron scale may facilitate research on miniaturized processes.
- **Personal and collective protection measures.** Research is required to determine how to use new materials and methods to develop protective clothing, new drugs and vaccines, and infrastructure protection (air filters, stronger construction materials, decontaminants).

b. Addressing research opportunities in manufacturing would better prepare the nation for a terrorist attack.

- **Minimization of the hazards of chemical transport and storage.** Chemical transport routes by rail, truck, or barge pass through population centers and neighborhoods. Large storage tanks of chemicals often exist at industrial sites. The inherent danger of chemical transportation and storage can be reduced if new manufacturing processes are developed that use less reactive, less harsh chemicals or produce and consume the dangerous chemicals only on demand and on site.
- **Rapid production scale-up procedures.** If these procedures are established before they are needed, they can be implemented immediately in an attack. Although investigation into scale-up of all stages of production should occur, the scale-up of separation and purification is a specific challenge.

c. Fundamental research in basic science and engineering is essential to meet these needs. Much basic research stems from the need to solve specific problems faced by society. Supporting fundamental research for national security and homeland defense will enable discovery and understanding in many areas of chemistry and chemical engineering. These areas include materials development, pharmaceutical modes of action, particulate air transport and dispersal, catalysis, chemical and biochemical binding, solids flow and crystallization, energy sources and batteries, and sampling methodology and preparation. Research in many of these areas will be needed to meet the challenges outlined above.

2. Infrastructure enhancements are needed to promote the success of research in national security and homeland defense.

- **a. Access to secure facilities.** Many important research efforts will require the use of hazardous materials, classified data, and specialized facilities. Collaboration with chemists, chemical engineers, and other scientists at government facilities will be necessary.
- **b. Transformation of graduate education.** Changes in the infrastructure of graduate education to remove barriers to interdisciplinary and multidisciplinary research will enable students to expand their range of knowledge and to learn how to work in concert with others to achieve maximum effectiveness. This will be needed for them to participate successfully in any research program after graduation, especially one centered on national security and homeland defense related issues.
- **c. Instrumentation for research.** Much of the needed research will depend strongly on new instrumentation to replace existing obsolete equipment as well as to allow new experiments. This includes major, multi-user equipment as well as specialized instrumentation for individual investigators.

CHALLENGES FOR THE CHEMICAL SCIENCES IN THE 21ST CENTURY

NATIONAL SECURITY & HOMELAND DEFENSE

COMMITTEE ON CHALLENGES FOR THE CHEMICAL SCIENCES IN THE 21ST CENTURY

BOARD ON CHEMICAL SCIENCES AND TECHNOLOGY

DIVISION ON EARTH AND LIFE STUDIES

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS • 500 Fifth Street, N.W. • Washington, D.C. 20001

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

Support for this study was provided by the American Chemical Society; the American Institute of Chemical Engineers; the Defense Advanced Research Projects Agency under Contract No. MDA972-01-M-0001; the Camille and Henry Dreyfus Foundation, Inc. under Contract No. SG00-093; the National Institute of Standards and Technology under Contract No. NA1341-01-W-1070; the National Institutes of Health/National Cancer Institute under Contract No. N0-OD-4-2139; the National Science Foundation under Contract No. CTS-9908440; the U.S. Department of Energy/ Basic Energy Science under Contract No. DE-FG02-00ER15040; the U.S. Department of Energy/ Office of Industrial Technologies under Contract No. DE-AT01-01EE41424; and the U.S. Environmental Protection Agency under Contract No. CR828233-01-0.

All opinions, findings, conclusions, or recommendations expressed herein are those of the authors and do not necessarily reflect the views of the organizations or agencies that provided support for this project.

International Standard Book Number 0-309-08504-7

Additional copies of this report are available from:

The National Academies Press
500 5th Street, N.W.
Box 285
Washington, DC 20055
800-624-6242
202-334-3313 (in the Washington Metropolitan Area)
http://www.nap.edu

Printed in the United States of America

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Wm. A. Wulf is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. Wm. A. Wulf are chair and vice chair, respectively, of the National Research Council.

www.national-academies.org

ORGANIZING COMMITTEE FOR THE WORKSHOP ON NATIONAL SECURITY AND HOMELAND DEFENSE

JOHN L. ANDERSON, Carnegie Mellon University, Co-Chair
JOHN I. BRAUMAN, Stanford University, Co-Chair
JACQUELINE K. BARTON, California Institute of Technology, Steering Committee Liaison
MARVIN H. CARUTHERS, University of Colorado
LIANG-SHIH FAN, Ohio State University
LARRY E. OVERMAN, University of California, Irvine
MICHAEL J. SAILOR, University of California, San Diego
JEFFREY J. SIIROLA, Eastman Chemical Company, Steering Committee and BCST Liaison

Staff

JENNIFER J. JACKIW, Program Officer
CHRISTOPHER K. MURPHY, Program Officer
SYBIL A. PAIGE, Administrative Associate
DOUGLAS J. RABER, Senior Scholar
DAVID C. RASMUSSEN, Program Assistant

COMMITTEE ON CHALLENGES FOR THE CHEMICAL SCIENCES IN THE 21ST CENTURY

RONALD BRESLOW, Columbia University, Co-Chair
MATTHEW V. TIRRELL, University of California, Santa Barbara, Co-Chair
JACQUELINE K. BARTON, California Institute of Technology
MARK A. BARTEAU, University of Delaware
CAROLYN R. BERTOZZI, University of California, Berkeley
ROBERT A. BROWN, Massachusetts Institute of Technology
ALICE P. GAST,[1] Stanford University
IGNACIO E. GROSSMANN, Carnegie Mellon University
JAMES M. MEYER,[2] E. I. du Pont de Nemours and Company
ROYCE W. MURRAY, University of North Carolina, Chapel Hill
PAUL J. REIDER, Amgen, Inc.
WILLIAM R. ROUSH, University of Michigan
MICHAEL L. SHULER, Cornell University
JEFFREY J. SIIROLA, Eastman Chemical Company
GEORGE M. WHITESIDES, Harvard University
PETER G. WOLYNES, University of California, San Diego
RICHARD N. ZARE, Stanford University

Staff

JENNIFER J. JACKIW, Program Officer
CHRISTOPHER K. MURPHY, Program Officer
SYBIL A. PAIGE, Administrative Associate
DOUGLAS J. RABER, Senior Scholar
DAVID C. RASMUSSEN, Project Assistant

[1]Committee member until July 2001; subsequently the Board on Chemical Sciences and Technology (BCST) liaison to the committee in her role as co-chair of the BCST.
[2]Meyer's committee membership ended March 2002, following his retirement from DuPont.

BOARD ON CHEMICAL SCIENCES AND TECHNOLOGY

Staff

Preface

Initially, the Challenges for the Chemical Sciences in the 21st Century project was designed to be a series of five workshops encompassing the main technological areas to which the chemical sciences contribute. After the events of September 11, 2001, it was recognized that chemists and chemical engineers have always contributed significantly to our nation's defense capabilities and that now they will play an increasingly important part in homeland security. Thus, the National Security and Homeland Defense Workshop was arranged on an emergency basis. It is hoped that the presentations and discussions at the workshop found in this report will help chemical scientists understand how their research can be applied to national security problems and will guide them in new directions to ultimately enhance the safety of U.S. civilians and military personnel.

In some cases, modified or improved existing technologies were identified as likely contributors to national security solutions, and in others, completely new technologies were called for. However, the workshop was not designed to provide specific recommended solutions to national security and homeland defense problems (see Appendix A for the Statement of Task). The workshop report is just that—a report of the proceedings of and discussions at the workshop that focused on research in chemistry and chemical engineering clearly related to national security. Topics in other areas of the chemical sciences are addressed in the other reports in the "Challenges" series including *Beyond the Molecular Frontier: Challenges for Chemists and Chemical Engineers* as well as in *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism*.

Following the workshop, the organizing committee met to reach preliminary consensus on the workshop findings and to create an outline for its report. The

report was fully developed through iterations among the committee members. In addition to summaries of the speaker presentations (Appendix D), the committee has attempted to capture participants' input from both the plenary and breakout sessions in the report chapters. Illustrative comments from presentations and subsequent discussions are highlighted in boxes interspersed throughout the chapters.

This study was conducted under the auspices of the NRC's Board on Chemical Sciences and Technology with assistance provided by its staff. The committee acknowledges this support.

John L. Anderson and John I. Brauman
Co-Chairs
Organizing Committee for the Workshop on
National Security and Homeland Defense

Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Peter K. Dorhout, Colorado State University
Catherine C. Fenselau, University of Maryland
Nancy B. Jackson, Sandia National Laboratories
C. Bradley Moore, Ohio State University
George Parshall, E. I. duPont de Nemours and Company (retired)
K. John Pournoor, 3M
Steven J. Sibener, University of Chicago
George M. Whitesides, Harvard University
Charles Zukoski, University of Illinois

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by R. Stephen Berry, University of Chicago. Appointed by the National Research Council, he was responsible for making

certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Contents

APPENDIXES